

METHOD FOR OPERATING AN INTERNAL COMBUSTION ENGINE

FIELD OF THE INVENTION

The present invention relates to a control unit and a method  
for operating an internal combustion engine of a motor  
5 vehicle, such that the internal combustion engine is  
controlled/regulated as a function of an air-mass sensor  
signal.

BACKGROUND INFORMATION

10 If a fault occurs in the air-mass sensor signal of the  
air-mass sensor, known operating methods have the disadvantage  
that the control/regulation of the internal combustion engine  
is influenced in such a way that the internal combustion  
15 engine will no longer operate at the optimal operating point.

When driving on a wet surface, for instance, spray water may  
get into an intake tract of the internal combustion engine,  
where it can penetrate an air filter and wet an air-mass  
20 sensor installed in the intake tract. This effect, which is  
also known as water entry, is particularly disadvantageous for  
the widely used hot-film air-mass sensors, which have a  
heating surface that cools when brought into contact with  
water in the liquid phase, with the result that the air-mass  
25 sensor signal generated by the air-mass sensor is distorted.

Using the distorted air-mass sensor signal, the control unit  
controlling/regulating the internal combustion engine  
calculates an incorrect value for the air-fuel ratio to be

set, so that the internal combustion engine no longer operates at the optimal operating point.

Furthermore, the emission values of the internal combustion engine are affected by water entry, since a portion of the introduced water or the water vapor generated therefrom reaches a combustion chamber of the internal combustion engine, where it displaces a portion of the air quantity required for combustion.

Accordingly, it is an object of the present invention to provide a method for operating an internal combustion engine that minimizes the influence of an interference variable, which affects the air-mass sensor signal, and in turn effects the regulation of the internal combustion engine.

#### SUMMARY

In accordance with the present invention, at least one first auxiliary signal is utilized, and the influence of an interference variable, which affects the air-mass sensor signal, and in turn effects the regulation of the internal combustion engine, is reduced as a function of the first auxiliary signal.

The inclusion of the first auxiliary signal according to the present invention makes it possible for the internal combustion engine to operate at the optimal operating point despite a fault in the air-mass sensor signal. Compared to conventional operating methods for internal combustion engines, an optimal power output of the internal combustion engine is ensured even when driving on wet surfaces, and compliance with legally mandated limit values for emissions of the internal combustion engine is ensured as well.

An advantageous example embodiment of the operating method

according to the present invention includes a comparison of the first auxiliary signal, or a signal derived from the first auxiliary signal, with the air-mass sensor signal, or a signal derived from the air-mass sensor signal, and a comparison result is obtained.

Comparing the first auxiliary signal with the air-mass sensor signal makes it possible to determine a fault of the air-mass sensor in the case of substantially different signal characteristics. In this manner, wetting of the heating surface of a hot-film air-mass sensor with water, for instance, is able to be detected. It is also possible to detect other types of faults of the air-mass sensor, for instance a signal cut-off of the sensor caused by mechanical damage to a signal line.

A direct comparison of a signal derived from the first auxiliary signal with the air-mass sensor signal or with a signal derived from the air-mass sensor signal is particularly advantageous. This makes it possible to include only certain signal components of the first auxiliary signal in the comparison.

Another example embodiment of the operating method according to the present invention includes obtaining a controlled variable for the control of the internal combustion engine as a function of the comparison result. The use of this controlled variable allows the control/regulation of the internal combustion engine to be adapted in such a way that a compensation of the influence of the disturbance variable on the air-mass sensor signal may take place.

In a variant of the method, the controlled variable may be obtained from the difference of a first auxiliary variable, interpreted as setpoint value for the air mass flowing into the intake tract, and the air-mass sensor signal.

In a further variant of this method, it is additionally possible to obtain the controlled variable from the first auxiliary signal alone; this is useful when the air-mass sensor signal deviates significantly from an expected value.

5 When the air-mass sensor is not available at all, the method according to the present invention will still allow the internal combustion engine to be operated at the optimal operating point.

10 Another advantageous example embodiment of the operating method according to the present invention includes obtaining the first auxiliary signal from state variables of the internal combustion engine, so that no additional external sensors are necessary to obtain the first auxiliary signal.

15 Instead, the first auxiliary signal may be ascertained from the position of a driver pedal, the rotational speed, the temperature, as well as other state variables of the internal combustion engine.

20 Another advantageous example embodiment of the present invention includes obtaining the first auxiliary signal from a signal of an exhaust-gas probe such as a lambda probe. In this embodiment, it is possible to subject the air-mass sensor signal to a plausibility check since, with knowledge of the  
25 injected fuel quantity, the fuel mass actually conveyed to the combustion chamber may be calculated from the signal of the exhaust-gas probe. In contrast to the air-mass sensor signal, the signal of the exhaust-gas analyzer probe is not greatly distorted by the water vapor in the combustion chamber.

30 If the first auxiliary signal deviates significantly from the air-mass value obtained from the air-mass sensor signal, a malfunction of the first air-mass sensor may be concluded, possibly due to water in the intake tract. In this case, the  
35 operating method according to the present invention makes it possible to, e.g., discard the faulty air-mass sensor signal

and substitute the first auxiliary signal as input variable for the control device of the internal combustion engine.

To consider the generally higher dynamics of a hot-film air-mass sensor compared to a lambda probe, the measured values of the air-mass sensor signal may be averaged. As an alternative, it is possible to connect a filter downstream from the air-mass sensor, which describes the dynamics of the controlled system of the lambda probe. If the internal combustion engine is a diesel gasoline engine, a lean-mixture sensor may be used as exhaust-gas probe.

A permanent comparison of the air-mass sensor signal with the signal from the exhaust-gas probe may take place within the framework of the afore-described plausibility control of the air-mass sensor signal, the controlled variable for regulating/controlling the internal combustion engine being obtained as a function of the comparison result.

In accordance with advantageous example embodiment of the operating method according to the present invention, the comparison includes the following steps: differentiating the air-mass sensor signal so as to obtain a differentiated air-mass sensor signal; differentiating the first auxiliary signal to obtain a differentiated auxiliary signal; and forming the difference from the differentiated air-mass sensor signal and the differentiated auxiliary signal to obtain a differential signal, the differential signal being a measure for the difference in the time change between the signal from the first air-mass sensor and the first auxiliary signal. The first auxiliary signal may be obtained from the state variables of the internal combustion engine or from the signal of an exhaust-gas probe and may be interpreted as setpoint value for the air mass.

If the differential signal exceeds a predefinable threshold

value, which corresponds to a dynamic response of the air-mass sensor signal that deviates significantly from the first auxiliary signal, a malfunction or a fault of the air-mass sensor is detected in this example embodiment. It is advantageous for simple processing of the differential signal if the differentiated air-mass sensor signal is scaled to a time average of the air-mass sensor signal, the differentiated auxiliary signal is scaled to a time average of the first auxiliary signal, and the absolute value of the differential signal is generated so as to obtain a positive differential signal. Finally, the differential signal is compared to at least one predefinable threshold value. If the afore-mentioned absolute-value generation is omitted, two threshold values for the differential signal must be selected accordingly.

The threshold value makes it possible to specify the maximum value or the extremal values of the differential signal at which a difference between the air-mass sensor signal and the first auxiliary signal is not yet interpreted as fault of the air-mass sensor signal.

In the case of a single threshold value and in the event that it is exceeded, the first auxiliary signal is obtained as controlled variable. The air-mass sensor signal is obtained as controlled variable if the comparison result indicates that the differential signal is smaller than or equal to the threshold value. An analogous procedure is proposed in the case of two threshold values.

In a further advantageous example embodiment of the operating method according to the present invention, the first auxiliary signal is obtained from a signal of a second air-mass sensor. The additional, second air-mass sensor, just like the exhaust-gas probe, allows a plausibility control of the air-mass sensor signal from the first air-mass sensor.

Another advantageous example embodiment of the present invention provides that the first auxiliary signal be obtained from a signal of an already present rain sensor of the motor vehicle. Rain sensors are used to control windshield wipers, for example, and the signals they provide may be utilized as a measure for the precipitation quantity. From the precipitation quantity, which is correlated to the interference variable influencing the air-mass sensor signal, namely the water quantity striking the heating surface of the hot-film air-mass sensor, the controlled variable may be ascertained.

Another example embodiment of the present invention provides that the first auxiliary signal is obtained from a signal of a capacitive sensor, the capacitive sensor being configured as integral component of the first air-mass sensor. A variant having an especially small design results from the fact that the surface of the already present first air-mass sensor is used as first capacitor plate of the capacitive sensor. A second capacitor plate of the capacitive sensor may be arranged in a housing of the first air-mass sensor, for example.

Another advantageous example embodiment of the present invention provides that the first auxiliary signal is obtained from a signal of an ohmic sensor, the ohmic sensor being configured as integral component of the first air-mass sensor. An advantageous example embodiment of the method according to the present invention provides that the ohmic sensor has at least two electrodes preferably made of a corrosion-resistant material. This ensures that the ohmic sensor is also suited for long-term operation.

A further example embodiment of the present invention provides for the ohmic sensor to be arranged on the surface of the first air-mass sensor.

In an advantageous further embodiment of the operating method according to the present invention, the first auxiliary signal is obtained from the signal of the capacitive sensor and the signal of the ohmic sensor. Water droplets striking the surface of the air-mass sensor are able to be detected in a reliable manner by changes in the capacitance or the conductivity of the respective sensor. If a hot-film air-mass sensor is used, an arrangement of the capacitive/ohmic sensor directly on the heating surface may be used.

Within the framework of the comparison, an advantageous example embodiment of the method according to the present invention provides for a difference to be formed from the first auxiliary signal and the air-mass sensor signal so as to obtain the controlled variable. The first auxiliary signal may be determined from the state variables of the internal combustion engine, such as the driver-pedal position, the rotational speed and additional variables. The first auxiliary signal in this case represents a setpoint value for the air mass to be conveyed to the internal combustion engine, the setpoint value being obtained from the state variables of the internal combustion engine. This allows a comparison with the air-mass signal actually detected by the air-mass sensor.

A filtering of the air-mass sensor signal prior to forming the difference is advantageous for obtaining a filtered air-mass sensor signal. In this way, only the signal frequencies of the air-mass sensor signal that are meaningful for the comparison are considered in the comparison. For example, when a low pass filter is used for filtering, high frequency signal components of the air-mass sensor signal are filtered out and will not be entered in the difference generation.

It is known that such high frequency signal components of the air-mass sensor signal are produced by water droplets hitting the heating surface of the air-mass sensor and by the related



spontaneous cooling of the heating surface.

These high frequency signal components may be considered an interference variable since they do not contain any directly analyzable information about the air mass entering via the intake tract and have an interfering effect on the difference formation and thus on the controlled variable as well. This is prevented by using a low pass filter according to the present invention. It is useful in this context to select the cut-off frequency of the low pass filter such that the low pass filter filters out the highest possible portion of the signal energy of the high frequency signal components so as to minimize the influence of the interference variable.

To this end, an example embodiment of the method according to the present invention provides that the cut-off frequency of the low pass filter be selected dynamically and as a function of state variables of the internal combustion engine. This allows an especially good suppression of the interference variable via the low pass filter. Furthermore, additional interfering signal components of the air-mass sensor signal whose spectrum depends on the operating state of the internal combustion engine may be suppressed in this manner.

An additional example embodiment of the operating method according to the present invention provides that the cut-off frequency of the low pass filter is selected as a function of a model of the internal combustion engine. A so-called system model of the internal combustion engine may be used as model, which provides information regarding the spectrum of allowed air-mass sensor signals in the respective state of the internal combustion engine as a function of the state variables of the internal combustion engine.

Using this information, the cut-off frequency of the low pass filter is able to be selected in such a way that only spectral

components of the air-mass sensor signal that are not caused by an interference effect are entered in the difference formation.

5 A further example embodiment of the method according to the present invention provides that the first auxiliary signal is obtained from the air-mass sensor signal by filtering with a high pass filter and is used as a controlled variable to control the internal combustion engine.

10 As already mentioned, it is known that water droplets striking the heating surface of a hot-film air-mass sensor cause high frequency signal components, which are able to be separated from the low frequency signal components of the air-mass  
15 sensor signal by the high pass filter utilized according to the present invention. In this case the first auxiliary signal is a measure for the water quantity striking the air-mass sensor and may be used as controlled variable.

20 In this embodiment as well, the selection of the cut-off frequency of the high pass is implemented dynamically and as a function of state variables of the internal combustion engine in order to increase the accuracy of the method, thereby preventing the possibility that the first auxiliary signal  
25 also contains signal components of a useful signal of the air-mass sensor.

Another example embodiment of the method according to the present invention provides a second auxiliary signal being  
30 obtained from the air-mass sensor signal via filtering with a low pass filter, and the controlled variable being obtained from the first auxiliary signal, the second auxiliary signal and state variables of the internal combustion engine. In this example embodiment, the first auxiliary signal constitutes a  
35 measure for the water quantity striking the air-mass sensor; the second auxiliary signal constitutes the actual useful

signal of the air-mass sensor representing the air mass  
flowing through the intake tract; and from the state variables  
of the internal combustion engine it is possible in turn to  
dynamically select a cut-off frequency of the low pass/high  
pass filter.

It is conceivable that the cut-off frequency of the low pass  
filter corresponds to the cut-off frequency of the high pass  
filter. To obtain a spectral separation of the first and the  
second auxiliary signal, a band stop may be utilized instead  
of the low pass filter and the high pass filter, the band  
stop's lower cut-off frequency matching the cut-off frequency  
of the low pass filter and its upper cut-off frequency  
matching the cut-off frequency of the high pass filter.

According to a further advantageous example embodiment of the  
present invention, the cut-off frequency of the high pass/low  
pass filter is selected as a function of a model of the  
internal combustion engine. As an alternative, it is also  
possible for the upper and the lower cut-off frequency of the  
band stop to be selected as a function of a model of the  
internal combustion engine.

Another advantageous example embodiment of the present  
invention provides two air-mass sensors arranged in an intake  
manifold of the internal combustion engine in such a way that  
air flowing into the intake manifold first reaches the first  
air-mass sensor and then the second air-mass sensor, which is  
located at a distance in the flow direction of the aspirated  
air, and the method includes the following steps within the  
framework of the comparison: delaying the air-mass sensor  
signal by a delay time so as to obtain a delayed air-mass  
sensor signal; subtracting the first auxiliary signal from the  
delayed air-mass sensor signal in order to obtain a  
differential signal; integrating the differential signal so as  
to obtain an indicator signal; differentiating the delayed

air-mass sensor signal to obtain a differentiated air-mass sensor signal; forming the amount of the differentiated air-mass sensor signal to obtain a positive air-mass sensor signal; differentiating the first auxiliary signal to obtain a differentiated auxiliary signal; forming the amount of the differentiated auxiliary signal to obtain a positive auxiliary signal; and subtracting the positive auxiliary signal from the positive air-mass sensor signal to obtain an additional differentiated signal.

The indicator signal obtained from the differentiated signal is a measure for the water quantity present in the intake manifold or in the intake tract; the operational sign of the additional differentiated signal indicates which one of the two air-mass sensors provides the greater signal change. According to the present invention, when a predefinable threshold value for the indicator signal is exceeded, i.e., in the case of water entry into the intake tract, the controlled variable is obtained from the indicator signal and the signal of the particular air-mass sensor for which the smaller signal change has been detected. This mechanism takes the fact into account that high-frequency signal components in the air-mass sensor signal are in all likelihood caused by water droplets striking the heating surface of an air-mass sensor, or originate from other interference effects and not from usually low-frequency changes in the air-mass flow through the intake tract that are appropriate to the operation.

Another advantageous example embodiment of the method according to the present invention provides that both air-mass sensors are arranged next to one another, that the delay step is omitted, and that the second air-mass sensor is provided with a water-droplet separator. In another example method according to the present invention, it is advantageous that a model simulating the dynamic response of the water-droplet separator is taken into account in the processing of the

air-mass sensor signal and/or the first auxiliary signal. The model makes it possible to consider the dynamic response of the second air-mass sensor, which is changed because of the water-droplet separator, thereby ensuring the comparability of the sensor signals from the first air-mass sensor and the second air-mass sensor.

Another example embodiment of the method according to the present invention provides both air-mass sensors being integrated in a shared sensor system, e.g., in a shared housing.

Another advantageous example embodiment of the method according to the present invention provides that the first air-mass sensor is designed as hot-film air-mass sensor.

The implementation of the method according to the present invention may be in the form of a computer program which is provided for a control unit of an internal combustion engine in a motor vehicle. The computer program has program codes suitable for carrying out the method according to the present invention when it is executed on a computer. Furthermore, the program code may be stored on a computer-readable data carrier, such as a flash memory. In these cases, the present invention is thus realized by the computer program.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of signal flow according to a first example embodiment of the method according to the present invention.

Figure 1a is a flow chart corresponding to the signal flow shown in Figure 1.

Figure 2 is a schematic illustration of signal flow according

to a second example embodiment of the present invention.

Figure 2a is a flow chart corresponding to the signal flow shown in Figure 2.

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Figure 3 is a schematic illustration of signal flow according to a third example embodiment of the method according to the present invention.

10 Figure 4 is a schematic illustration of the arrangement of the hot-film air-mass sensors HFM\_1, HFM\_2 in intake manifold 4, as well as the associated signal flow.

15 Figure 4a is a flow chart of the third example embodiment of the method according to the present invention.

Figure 5 shows a schematic illustration of an internal combustion engine according to the present invention.

20 DETAILED DESCRIPTION

Figure 1 shows a signal flow of a first example method according to the present invention, in which a first auxiliary signal H\_1 and an air-mass sensor signal L\_1 from a first  
25 hot-film air-mass sensor HFM\_1 (Figure 5) are analyzed. Air-mass sensor HFM\_1 is arranged in intake tract 3 of an internal combustion engine 1 (Figure 5), and emits a signal L\_1 whose value is proportional to the air mass flowing through the intake tract.

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The evaluation of signals L\_1, H\_1 makes it possible to reduce the influence of an interference variable, which affects air-mass sensor signal L\_1, and in turn effects the control/regulation of internal combustion engine 1 implemented  
35 by control unit 2. The time sequence of the method steps for the evaluation may be seen from the flow chart of Figure 1a.

As can be seen in Figure 1, auxiliary signal H<sub>1</sub> is obtained from the following state variables of internal combustion engine 1: pressure P of the fresh air outside intake tract 3; temperature T of the fresh air; and the rotational speed n of internal combustion engine 1; additional state variables (not shown) of internal combustion engine 1 may also be used, as well. Auxiliary signal H<sub>1</sub> indicates the air mass determined from state variables P, T, n with the aid of the general gas equation, the air mass being the air mass required by internal combustion engine 1 during the operation with state variables P, T, n.

First auxiliary signal H<sub>1</sub> is conveyed to differentiator 20, which, in step 211 of the flow chart of Figure 1a, forms a differentiated auxiliary signal H<sub>1\_1</sub> from first auxiliary signal H<sub>1</sub>.

Next, in step 211a of Figure 1a, differentiated auxiliary signal H<sub>1\_1</sub> is scaled to a time average H<sub>1\_m</sub> of first auxiliary signal H<sub>1</sub>.

In parallel with steps 211, 211a, air-mass sensor signal L<sub>1</sub> of first air-mass sensor HFM<sub>1</sub> (Figure 5) is transmitted to a further differentiator 21 (Figure 1), which takes place in step 210 of Figure 1a. Differentiator 21 of Figure 1 delivers a differentiated air-mass sensor signal L<sub>1\_1</sub>, which, in a following step 210a (Figure 1a), is scaled to a time average L<sub>1\_m</sub> of air-mass sensor signal L<sub>1</sub>.

The difference generation from differentiated air-mass sensor signal L<sub>1\_1</sub> and differentiated auxiliary signal H<sub>1\_1</sub> in subtractor 22 (Figure 1), which follows in step 220, yields a differential signal D<sub>1\_1</sub>. Finally, in step 230, the amount of differential signal D<sub>1\_1</sub> is formed so as to obtain a positive differential signal D<sub>1\_1'</sub>, which is filtered by a filter 23 in following step 240.

Filtered differential signal D<sub>1\_1</sub>\* is compared in a comparator 24 with a predefinable threshold value S<sub>1</sub> in order to obtain a comparison result VE. The comparison of filtered differential signal D<sub>1\_1</sub>\* with predefinable threshold value S<sub>1</sub> takes place in step 250 of Figure 1a.

Two possible comparison results VE exist in comparison 250 with predefinable threshold value S<sub>1</sub> for filtered differential signal D<sub>1\_1</sub>\*, which is always positive due to the amount generation in step 230.

Differential signal D<sub>1\_1</sub> indicates the difference between the time change of air-mass sensor signal L<sub>1</sub> of first air-mass sensor HFM<sub>1</sub> and the time change of first auxiliary signal H<sub>1</sub>. For as long as differential signal D<sub>1\_1</sub> does not exceed a selected limit value, it is assumed that no interference influence of signal L<sub>1</sub> from air-mass sensor HFM<sub>1</sub> exists. In this case, signal L<sub>1</sub> is obtained as controlled variable R (Figure 1a).

However, as soon as the limit value is exceeded, it is assumed that an interference influence of signal L<sub>1</sub> is present, which represents the cause of the deviating dynamic response of signals L<sub>1</sub>, H<sub>1</sub>. In this case, first auxiliary signal H<sub>1</sub> is obtained as controlled variable R, i.e., control unit 2 shown in Figure 5 does not receive a signal L<sub>1</sub> from an external sensor as input variable for the air flowing through intake tract 3, but a variable that is calculated in control unit 2 itself.

The interference influence may stem from interferences resulting from high-frequency electromagnetic radiation in the area of connecting lines of air-mass sensor HFM<sub>1</sub>. Another cause may be attributable to water droplets striking the heating surface of air-mass sensor HFM<sub>1</sub> and the spontaneous cooling of the heating surface that accompanies it.



The method according to the present invention prevents speed fluctuations or a sudden drop in the output of internal combustion engine 1, and also the exceeding of limit values for the emissions of internal combustion engine 1: this is due to the fact that in a malfunction of air-mass sensor signal L\_1, auxiliary signal H\_1 is substituted as controlled variable R or as input variable for control unit 2 of internal combustion engine 1.

The signal flow of a second example embodiment of the present invention is shown in Figure 2, which simultaneously represents a closed-loop control circuit of internal combustion engine 1. The associated method flow chart may be seen from Figure 2a.

As can be seen from Figure 2, air-mass sensor HFM\_1 provides an air-mass sensor signal L\_1, which is obtained from the value of the air mass in intake tract 3 of internal combustion engine 1 and an interference variable S\_X that is superposed onto this value.

As already mentioned, interference variable S\_X represents signal interferences of air-mass sensor signal L\_1, which are caused, for instance, by water droplets striking the heating surface of air-mass sensor HFM\_1.

According to Figure 2a, signal L\_1 is first filtered by a low pass filter 340a in a step 340, which results in a filtered air-mass sensor signal L\_1\*. Filtered air-mass sensor signal L\_1\* is subsequently subtracted from an auxiliary signal H\_1 in a step 380.

As in the previous example, auxiliary signal H\_1 is arithmetically obtained from state variables P, T, n of internal combustion engine 1. Difference generation 380 provides controlled variable R, which is supplied as input

variable to control unit 2 and influences the regulation of internal combustion engine 1.

Controlled variable R acts on a closed-loop control circuit for the exhaust-gas recirculation, for instance. This makes it possible to adjust the air-fuel mixture conveyed to internal combustion engine 1 to an optimal value.

In the ideal state, controlled variable R assumes the value zero, i.e., the air mass recorded by air-mass sensor HFM\_1 is as large as the arithmetically determined air mass of auxiliary signal H\_1. As soon as interference variable S\_X assumes a value other than zero, for instance when water enters the intake tract, a non-zero value results for controlled variable R as well.

To prevent the interference variable S\_X from influencing the regulation of the exhaust-gas recirculation, air-mass sensor signal L\_1 is filtered by low pass filter 340a. On the basis that interference variable S\_X usually provides high-frequency signal components compared to the air mass to be measured, in particular when water has entered intake tract 3, the cut-off frequency of low pass filter 340a is selected such that only low-frequency signal components of air-mass sensor signal L\_1 are allowed to pass and are thus considered when determining controlled variable R. High frequency signal components attributable to the interference variable will not be allowed to pass by 340a and are thus unable to influence the formation of controlled variable R.

It is advantageous to select the cut-off frequency dynamically, i.e., during operation of internal combustion engine 1, that is to say, as a function of a so-called system model of internal combustion engine 1. The system model provides information concerning the spectrum of air-mass sensor signal L\_1 as a function of state variables P, T, n.

This information also includes the highest signal frequency of signal L<sub>1</sub> to be expected. On the basis of this information it is possible to include in the generation of controlled variable R only that part of the spectrum of signal L<sub>1</sub> that indicates the actually recorded air mass.

Figure 3 shows the signal flow according to an example embodiment of the present invention, which includes both a high pass filter 440a and also a low pass filter 442a.

On the basis of air-mass sensor signal L<sub>1</sub> of air-mass sensor HFM<sub>1</sub>, first auxiliary signal H<sub>1</sub> is obtained from high-pass filtering of signal L<sub>1</sub> using high-pass filter 440a. Second auxiliary signal H<sub>2</sub> is obtained from low-pass filtering of signal L<sub>1</sub> using low pass filter 442a.

Controlled variable R is obtained from the two auxiliary signals H<sub>1</sub>, H<sub>2</sub>, analogously to the previous examples, from state variables (not shown in Figure 3) of internal combustion engine 1 (cf. Figure 5).

In this embodiment, the water quantity in intake tract 3 of internal combustion engine 1 is represented by auxiliary signal H<sub>1</sub>, which, due to the high-pass filtering, includes only the signal components stemming from the water droplets striking the heating surface of sensor HFM<sub>1</sub>.

The low-frequency signal components of air-mass sensor signal L<sub>1</sub>, which indicate the actual air-mass flow, form second auxiliary signal H<sub>2</sub>.

The cut-off frequencies of filters 440a, 442a are selected as a function of a model of internal combustion engine 1 and are dynamically adapted to the individual operating state.

With knowledge of the water quantity in intake tract 3 from

first auxiliary signal H\_1, the actual air mass from second auxiliary signal H\_2, and from state variables of internal combustion engine 1 (as well as possibly additional parameters of the combustion), it is possible to calculate the air mass actually available in the combustion chambers of internal combustion engine 1.

Even with water in its liquid phase present in intake tract 3 of internal combustion engine 1, it is possible to operate internal combustion engine 1 at the optimal operating point.

Another example embodiment of the present invention is shown in Figure 4. Two hot-film air-mass sensors HFM\_1, HFM\_2 are arranged in intake manifold 4 at a clearance D with respect to one another. The arrow indicates the flow direction of the air flowing into intake manifold 4.

As can be gathered from Figure 4, first air-mass sensor HFM\_1 is first surrounded by an inflowing air volume, and, following a propagation delay as a function of clearance D, second hot-film air-mass sensor HFM\_2 is surrounded by the inflowing air volume as well.

First sensor HFM\_1 provides air-mass sensor signal L\_1, and second sensor HFM\_2 provides first auxiliary signal H\_1. To compensate for the propagation-delay difference between air-mass sensor signal L\_1 and first auxiliary signal H\_1 caused by clearance D, timing element 510a is provided. It delays (cf. flow chart Figure 4a) air-mass sensor signal L\_1 by the time required by an air volume flowing into intake manifold 4 to travel from first sensor HFM\_1 to second sensor HFM\_2 and provides delayed air-mass sensor signal L\_1\_delta\_T, which is subsequently differentiated in differentiator 540a so as to obtain a differentiated air-mass sensor signal L\_1\_delta\_T\_1. The delay time of timing element 510a is adjustable and is selected such that the difference from

signals L\_1\_delta\_T and H\_1 is zero when no water is present in intake manifold 4.

5 First auxiliary signal H\_1 provided by second sensor HFM\_2 is differentiated in differentiator 542a to obtain a differentiated auxiliary signal H1\_1. Both differentiators 540a, 542a also perform an amount generation, so that a positive air-mass sensor signal L\_1\_delta\_T\_1' and a positive auxiliary signal H1\_1', respectively, are present at the  
10 individual outputs.

15 Finally, positive auxiliary signal H1\_1' is subtracted from positive air-mass sensor signal L\_1\_delta\_T\_1' in order to obtain a further differential signal Z\_Diff.

20 Furthermore, first auxiliary signal H\_1 is subtracted from delayed air-mass sensor signal L\_1\_delta\_T, and resulting differential signal D\_L\_H is integrated in integrator 530a so as to obtain an indicator signal A\_L\_H.

25 The indicator signal is a measure for the deviation of the signals measured by sensors HFM\_1, HFM\_2; from this deviation it is possible to determine the water quantity introduced in intake manifold 4. Differential signal Z\_Diff indicates which one of the two sensors HFM\_1, HFM\_2 detects a greater signal change.

30 As soon as indicator signal A\_L\_H exceeds a predefinable threshold value, controlled variable R (not shown in Figure 4) is obtained either from air-mass sensor signal L\_1 or from first auxiliary signal H\_1.

35 To obtain the most reliable value for the measured air mass for forming controlled variable R, the sensor signal whose signal change is smaller is used to form controlled variable R in this case.

If differential signal  $Z\_Diff > 0$ , the signal change of air-mass sensor signal  $L\_1$  is greater than the signal change of first auxiliary signal  $H\_1$ ; in this case, air-mass sensor signal  $L\_1$  is ignored and controlled variable  $R$  is generated from first auxiliary signal  $H\_1$ . In an analogous manner, controlled variable  $R$  is formed from air-mass sensor signal  $L\_1$  in a negative differential signal  $Z\_Diff$ .

With the aid of indicator signal  $A\_L\_H$  from which the introduced water quantity may be determined, and using the individual, not ignored sensor signal as a measure for the actual air quantity in intake tract 3, controlled variable  $R$  is able to be formed so as to calculate the correct fuel quantity to be injected as a function of the air mass actually available in the combustion chamber.

Both air-mass sensors  $HFM\_1$ ,  $HFM\_2$  may also be arranged next to one another in intake manifold 4, second air-mass sensor  $HFM\_2$  being provided with a water separator (not shown). Since the water separator modifies the dynamic response of second air-mass sensor  $HFM\_2$ , a model of the dynamic response of the water-droplet separator is connected downstream from first air-mass sensor  $HFM\_1$  in order to ensure comparability of the two sensor signals.

In this embodiment, a deviation of the sensor signals of both air-mass sensors  $HFM\_1$ ,  $HFM\_2$  provides a measure for the water quantity that has entered intake manifold 4. Both air-mass sensors  $HFM\_1$ ,  $HFM\_2$  may be arranged in the same housing.